

**Claims**

**What is claimed is:**

1. A method for determining an opacity value of an emission plume the method comprising the steps of:

5 directing a beam comprising at least two different wavelengths  
of electromagnetic radiation through an emission plume;  
detecting the beam after the beam has passed through the  
emission plume;  
determining a change in intensity of the beam for each of the at  
10 least two different wavelengths of electromagnetic  
radiation;  
comparing the change in intensity for a predetermined number of  
measurements of the at least two different wavelengths of  
electromagnetic radiation, and, if the change in intensity  
15 for the predetermined number of measurements of the at  
least two different wavelengths of electromagnetic  
radiation is substantially equivalent,  
determining an opacity value related to the change in intensity  
for the predetermined number of measurements of the at  
20 least two different wavelengths of electromagnetic  
radiation.

2. The method of claim 1, wherein the beam further comprises:
- a first wavelength that is substantially in the infrared spectrum;
  - a second wavelength that is substantially in the visible spectrum;
  - and
  - 5 a third wavelength that is substantially in the ultra-violet spectrum.
3. A method for measuring opacity using a remote emission sensing system that measures on-road vehicle exhaust emissions, the method
- 10 comprising:
- directing at least two different wavelengths of electromagnetic radiation through an exhaust emission plume;
  - detecting the at least two wavelengths of electromagnetic radiation after they pass through the exhaust emission
  - 15 plume;
  - determining the relative concentration of a vehicle exhaust constituent present in the exhaust emission plume;
  - determining a change in intensity for each of the at least two different wavelengths of electromagnetic radiation;
  - 20 correlating the change in intensity for each of the at least two different wavelengths of electromagnetic radiation to the determined relative concentration of the vehicle exhaust constituent;

registering a valid opacity value for each of the at least two  
different wavelengths of electromagnetic radiation that  
substantially correlate to the determined relative  
concentration of the vehicle exhaust constituent;  
5 comparing the change in intensity for a predetermined number of  
the at least two different wavelengths of electromagnetic  
radiation and, if the change in intensity for the  
predetermined number of the at least two different  
wavelengths of electromagnetic radiation is substantially  
10 equivalent,  
calculating a reported opacity value proportional to an average of  
the valid opacity values.

4. The method of claim 3, further comprising:  
15 directing a third different wavelength of electromagnetic  
radiation through the exhaust emission plume.
5. The method of claim 4 wherein,  
a first of the at least two different wavelengths of  
20 electromagnetic radiation comprises a wavelength that is  
substantially in the infrared spectrum;  
a second of the at least two different wavelengths of  
electromagnetic radiation comprises a wavelength that is  
substantially in the visible spectrum; and

the third different wavelength of electromagnetic radiation  
comprises a wavelength that is substantially in the ultra-  
violet spectrum.

- 5    6.    A system for measuring an opacity value for an exhaust emission plume,  
the system comprising:

a source of electromagnetic radiation that is directed through an  
exhaust emission plume;

10       a detector that detects the electromagnetic radiation and outputs a  
detector signal proportional to the detected  
electromagnetic radiation; and

a processor that receives the detector signal and calculates an  
opacity value for the exhaust plume based, at least in part,  
upon the detector signal.

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7.    The system of claim 6 wherein the source of electromagnetic radiation  
further comprises:

one or more sources that emit electromagnetic radiation in a first  
wavelength region, a second wavelength region and a  
20       third wavelength region.

8.    The system of claim 7 wherein  
the first wavelength region is substantially in the infrared region;

the second wavelength region is substantially in the visible  
region; and  
the third wavelength region is substantially in the ultra-violet  
region.

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9. The system of claim 7 wherein

the detector is enabled to detect electromagnetic radiation in each  
of the first, second and third wavelength regions and  
outputs a signal proportional to a detected intensity at  
each of the first, second and third wavelength regions;  
and

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the processor further comprises:

a comparison module that compares the detected intensity  
of each of the first, second and third wavelength  
regions.

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10. The system of claim 9 wherein

the processor further comprises:

an opacity determination module that determines an  
opacity value proportional to the change in  
intensity for the detected intensity of each of the  
first, second and third wavelength regions.

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11. A remote sensing system for measuring opacity of a vehicle exhaust  
plume the system comprising:

a source that directs at least two different wavelengths of  
electromagnetic radiation through an exhaust emission  
plume;

a detector that detects the at least two different wavelengths of  
electromagnetic radiation and produces an output signal;  
and

a processor comprising:

a relative concentration module that determines a relative  
concentration of a vehicle exhaust constituent  
present in the exhaust emission plume;

a change in intensity module that determines a change in  
intensity for the at least two different wavelengths  
based, at least in part, upon the output signal;

a correlation module that correlates the change in  
intensity for the at least two different wavelengths  
to the relative concentration of the vehicle exhaust  
constituent and registers a valid opacity value for  
each of the at least two different wavelengths that  
substantially correlate to the determined relative  
concentration of the vehicle exhaust constituent;  
and

a calculation module that compares the change in  
intensity for a predetermined number of the at  
least two different wavelengths of  
electromagnetic radiation and, if the change in  
intensity for the predetermined number of the at  
least two different wavelengths is substantially  
equivalent, calculates a reported opacity value  
proportional to the average of the valid opacity  
values.

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12. The system of claim 11 further comprising:  
a source of electromagnetic radiation comprising a third different  
wavelength.

15 13. The system of claim 12 wherein,  
a first of the at least two different wavelengths of  
electromagnetic radiation comprises a wavelength that is  
substantially in the infrared spectrum;  
a second of the at least two different wavelengths of  
electromagnetic radiation comprises a wavelength that is  
substantially in the visible spectrum; and  
the third different wavelength comprises a wavelength that is  
substantially in the ultra-violet spectrum.

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14. A method for calculating an opacity value for an exhaust emission plume, the method comprising:

obtaining an measurement of an exhaust constituent amount ( $n$ )

in a spatial volume of an exhaust emission plume;

5 directing a beam of substantially monochromatic electromagnetic

radiation substantially through the spatial volume of an

exhaust emission plume;

measuring a transmittance ( $T$ ) of the beam of substantially

monochromatic electromagnetic radiation;

10 calculating an opacity value ( $K_s$ ) proportional to the relation

$$K_s = \frac{\ln\left(\frac{1}{T}\right)}{n}.$$

15. The method of claim 14 wherein the measurement of an exhaust constituent amount comprises a measurement of an amount of carbon  
15 dioxide ( $n_{CO2}$ ).

16. The method of claim 14 wherein the beam of substantially monochromatic electromagnetic radiation comprises:

a beam of substantially ultra-violet radiation.

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17. A system for determining an opacity value for an exhaust emission plume, the system comprising:



an exhaust constituent amount measuring system that measures  
an exhaust constituent amount ( $n$ ) in a spatial volume of  
an exhaust emission plume;  
a source of substantially monochromatic radiation capable of  
5 forming a beam of radiation;  
a transmittance measuring system that measures a transmittance  
( $T$ ) of the beam of radiation; and  
a processor further comprising:  
an opacity calculation module that calculates an opacity  
10 value ( $K_s$ ) according to the relation

$$K_s = \frac{\ln\left(\frac{1}{T}\right)}{n}.$$

18. The system of claim 17 wherein the source of substantially  
monochromatic radiation produces ultra-violet radiation.
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19. The system of claim 17 wherein the exhaust constituent amount  
measuring system measures an amount of carbon dioxide ( $n_{CO2}$ ).
20. The system of claim 17 wherein the exhaust constituent amount  
20 measuring system measures an amount proportional to the sum carbon  
monoxide and carbon dioxide ( $n_{CO} + n_{CO2}$ )